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Preparation and application of fine-grinded cement in cement-based material

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HIGHLIGHTS

- GC was prepared by grinding PC with surface modifier and micro-grinding media.
- The surface modifier can control the early hydration process.
- The MGM can promote the grinding efficiency.
- GC can increase the cementitious efficiency and improve the cement microstructure.
- The compressive strength can be obviously enhanced with an optimal dosage of 20% GC.

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ABSTRACT

Low water/cement ratio in cement-based materials can be obtained with the incorporation of the superplasticizer. However, another problem can be found: the hydration degree of the cement minerals is obviously reduced. Generally, the hydration degree can be promoted with finer particle size, while this also brings about the problem of too fast hydration process at very early age, resulting in little contribution to the mechanical performance. Additionally, the stability in storage and transportation process is also a concern that cannot be ignored. In this study, the fine-grinded cement (GC) was prepared in the presence of surface modifier and micro-grinding media (MGM), with intention to control the early hydration process and promote the grinding efficiency. The hydration products, porosity and interfacial transition zone (ITZ) of Portland cement (PC) paste or mortar with GC were investigated. The results show that the efficiency of GC preparation can be promoted and the hydration process in the early age can be controlled with the addition of the surface modifier and MGM. Partial replacement of PC by GC, with an optimal dosage of 20% GC, can obviously increase the cementitious efficiency, resulting in an obvious enhancement to the compressive strength. The hydration degree, pore structure and the microstructure in ITZ can be improved in the presence of GC, in comparison with PC single system. Such results can provide guidance on the design of the cementitious component system in concrete mixing plant.

1. Introduction

In recent year, the application of superplasticizer significantly improves the basic performance of the cement-based materials in terms of workability, mechanical properties, porosity, and durability. Even though the water/cement ratio is declined obviously in the presence of superplasticizer, the excellent workability can also be obtained [1–4]. However, with the low water/cement ratio, another problem can be found: the hydration degree of the cement minerals is obviously reduced, which means that a large amount of cement minerals cannot contribute to cementitious performance directly. It has been reported that abundant cement minerals, possibly more than 20%, have not been hydrated to contribute to the cementitious performance [5]. If the hydration of these cement clinkers could be promoted, the basic performance of the cement-based materials, in particular for the cementitious properties, would have a rise [6]. Therefore, effective utilization of these unhydrated cement minerals has a considerable potential in optimizing the cement component.

It is generally believed that particle size of the cement is of great importance to the hydration degree at the very early hydration stage, and finer cement particles bring about a higher hydration degree [7]. However, very little application of finer cement can

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be found in real concrete, but widely used in the grouting of fine fissures, because the hydration process of these finer particles is too fast to be controlled, generally resulting in higher hydration heat, with almost no contribution to cementitious performance. It has also been reported that cement particle with the size less than 3 μm cannot contribute to the strength, mainly because the hydration products generated by the fast hydrated cement minerals would be destroyed in the mixing process. Furthermore, Geymayer et al. [8] reported some particular characteristics observed during the hydration process of Ultra-Fine Cement (UFC): (1) very short setting time; (2) compressive strength retrogression taking place few days after cement paste hardening. To solve this problem, Sarkar [18] et al. reported that improvements in setting characteristics and strength development were achieved in an ultrafine cement with a specific surface area >7000 cm^2/g which was prepared with addition of small dosages of a solid retarder and a solid water reducer. However, the stability of these finer particles in the process of transportation and storage is also hard to be controlled, and the preparation of UFC would cost a large amount of energy consumption.

If the hydration process of finer cement could be controlled at the early stage, cementitious efficiency of cement minerals would be increased obviously, thereby cutting down the total amount of cement minerals to achieve the same cementitious level [9]. Furthermore, if this finer cement could be prepared and used out within a short time in concrete mixing plant, the problem of storage and transportation would be avoided. In this case, the decline in carbon emission and the consumption of the energy would be gained [10]. The objective of this study is, therefore, to explore the possibility of the enhancement in cementitious efficiency by partly replacing cement with fine-grinded cement [11,12]. The commonly used cement was ground, with a surface modifier and micro-grinding media, to prepare the fine-grinded cement (GC), and then the GC was used to partly replace the common PC. It is worth noting that GC prepared in this study is different from the ultra-fine cement (UFC). UFC is much finer than PC or GC, and the preparation would cause much power, with the problem in the process of transportation and storage. Hydration heat, and particle size were characterized to assess the performance of the GC. Compressive strength, hydration products and microstructure of the cement with GC were investigated. It was anticipated that the results would suggest a new method to optimize the cementitious component system in concrete mixing plant.

2. Experimental

2.1. Materials

2.1.1. Cement

A Portland cement (P.I 42.5, PC), in accordance with the requirements of GB175-2007 Chinese standard, was used. Experimental measurement of X-ray Fluorescence (Axios advanced, made by PANalytical B.V., Holland) reveals the chemical composition of the PC as shown in Table 1. And the physical and mechanical properties are listed in Table 2.

2.1.2. Micro-grinding media

The main component of the micro-grinding media (MGM) is SiO_2, with excellent abrasion resistance and chemical stability, and its Mohs hardness is greater than 7. It is a kind of grinding medium with its size finer than the traditional large grinding medium, and can increase the touchpoints between cement and large grinding media (steel balls or cylpebs) to promote the grinding efficiency. The particle size distribution is listed in Table 3.

2.1.3. Surface modifier

The surface modifier, which is used to improve the surficial performance of the cement particles in grinding process and control the hydration process in mixing process, was prepared with industrial-grade triisopropanolamine, industrial-grade molasses and water with a proportion of 1:1:3 by weight.

Molasses is a kind of by-product from sugar industry, and it is often used as the auxiliary agent for grinding in cement industry.

Triisopropanolamine ($C_9H_{21}NO_3$) is also a kind of common auxiliary agent for grinding. Its molecular structure is shown in Fig. 1

2.1.4. Preparation for the fine-grinded cement

PC and MGM were mixed at proportion of 9:1 by weight. The surface modifier (1.0 wt% of this mixture) was added into the mixture, and then, the mixture was grinded by the standard mill for 20 min. This powder was marked as GC. The PC, which was grinded by the standard mill for 20 min without any surface modifier and MGM, was marked as PC (ground directly).

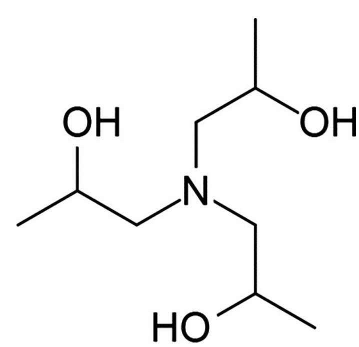

Fig. 1. Molecular structure of triisopropanolamine.

Table 1
Chemical composition of cement.

Compounds	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	Na_2O	SO_3	Loss
%	22.65	60.44	5.44	2.86	3.75	0.19	2.47	2.15

Table 2
Physical and mechanical properties of cement samples.

Setting time/min		Soundness	Compressive strength/MPa		
Initial	Final		1 d	7 d	28 d
110	150	Qualified	14.8	44.5	48.9

Table 3
Particle size distribution of micro grinding media/%

<0.08/mm	0.08–0.16/mm	0.16–0.5/mm	0.5–1/mm	1–1.6/mm	1.6–2/mm
1	12	25	31	23	8